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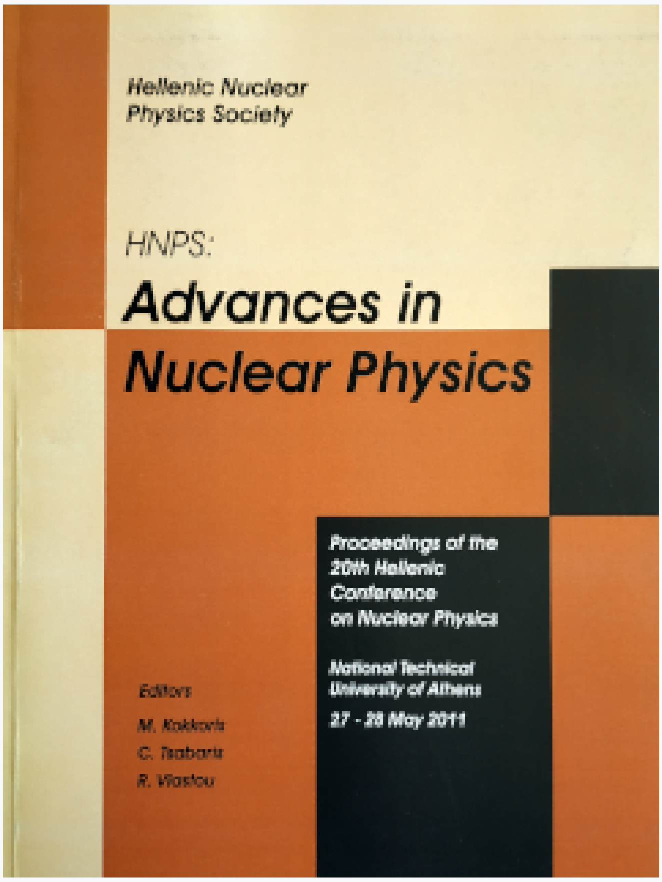

Dispersion of 137Cs concentration in the basins of the Aegean Sea

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Dispersion of ^{137}Cs concentration in the basins of the Aegean Sea

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Abstract

The anthropogenic radionuclide ^{137}Cs is used as a valuable oceanographic tracer for the study of sea water masses identification and water movement. In the present work, ^{137}Cs activity concentrations have been investigated in deep basins of Aegean Sea. Seawater samples were collected from five different sampling stations, during scientific oceanic campaigns from the period March to April 2008. The applied methodology was based on the adsorption of radiocaesium from dissolved AMP (Ammonium Phosphomolybdate Hydrate) in 20 L water samples. Moreover, during the pre-concentration procedure, the ^{134}Cs was used as reference tracer for determining the chemical efficiency and consequently to measure the activity concentration in a High Purity Ge detector. In terms of vertical records, the activity concentration in the selected basins ranged between 3-8.5 Bq m^{-3}, depending on the region and the depth of the basins. The higher concentration (8.5 Bq m^{-3}) was found in the region between Lemnos Island and the narrows of Dardanelles. The maximum concentrations were observed at the North Aegean Sea basins, between 20 and 40 m of depth, caused by the water masses coming from the Black Sea. At the Cretan Sea the vertical activity concentration of ^{137}Cs was homogeneous down to 2000 m depth, with an exception at the 800 m where it was decreasing significantly due to the transient deep-water masses from Adriatic Sea.

Keyword : Deep basin; ^{137}Cs; Ammonium Phosphomolybdate Hydrate; HPGe; Aegean Sea

1. Introduction

One of the most important artificial radionuclide is ^{137}Cs. Its half-life is about 30 years, it is gamma/beta ray emitter and its bioaccumulation by organisms (as an alkali metal) follows the metabolic route of potassium, which is an essential element for life [1].

The major sources of ^{137}Cs to the Mediterranean Sea are the fallout from nuclear weapon testing in the early 1960's and from the Chernobyl accident in 1986. The Chernobyl fallout produced a marked, but inhomogeneous input, where the maximum value appeared in the eastern Mediterranean and in the Adriatic Sea [3].

The marine environment is a dynamic system and radionuclides, which are introduced to surface waters by liquid discharges (wet and dry), do not remain in steady-state conditions due to currents and other physical processes in the water

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column. The water masses are transported both horizontally and vertically to different regions, as well as to the bottom waters (>900 m depth) and the sediments. The marine environment acts as the final repository of the terrestrial radioactive load removed by weathering processes carried by rivers [2].

In this work seawater samples were analyzed for ^{137}Cs to study the water masses and to understand the transport processes in a marine environment. This work includes an exploration, which was carried out in March and April 2008. There were five sampling stations, shown in Fig. 1, two of them at the deep basins (one at North Aegean (A1) with bottom depth 1550 m and the other at South Aegean (A10) with depth 1790 m) and the other three in the region of Dardanelles Straits, close to the exit (mouth) at the Aegean Sea (A2), southeast of Lemnos Island (NA1) and southwest of Samothrace Island (NA8).

2. Study area and methodology

The Aegean Sea has a surface area of about 1.8×10^{11} m^2, a volume of 8.5×10^{13} m^3 and a mean depth of 450 m (Fig.1). It consists of three sub-basins: the North Aegean, covering the area north of the North-Sporades and Lemnos islands, the Central Aegean, between the above-mentioned islands and the Cyclades, and the South Aegean, bounded by the Cyclades archipelago to the north and the island of Crete to the south.

The topography of the Aegean Sea, as well as the connection to the Black Sea through the Dardanelles Strait System, and the Ionian and Levantine basins, through the Straits of the Cretan Arc, determine the hydrological structure of the basin. The Dardanelles exit provides the Aegean Sea with a brackish, cold, light and very thin (20-40 m) surface layer (BSW), which covers the North Aegean and propagates southwards along the western shores of the sea, following a generally cyclonic (counter-clockwise) circulation [4]. The intermediate layer of the Sea, down to the shelf and sill level of 400 m, is occupied by water of Levantine origin, entering the Aegean through the eastern straits of the Cretan Arc and also following a cyclonic circulation. This Levantine water-mass also extents all the way to the surface along the eastern shores of the Central Aegean, where the BSW surface water layer is not present. The deeper than 400 m waters, of local origin, fill laterally isolated basins. The evolution of these waters is determined solely by vertical turbulent diffusion during stagnation periods [5].

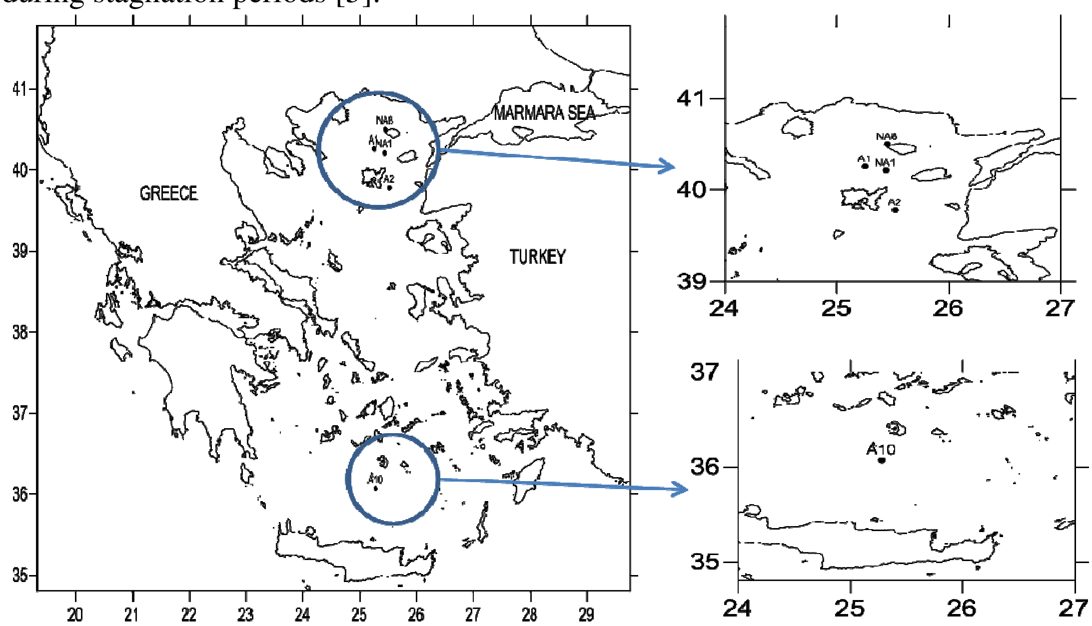

Fig. 1. The sampling locations from deep basins of the Aegean Sea in northeastern Mediterranean.

Nineteen seawater samples were collected from all the stations in total (2 -6 in each station, depending on the station's depth). The seaweater samples were stored in 20 L water tanks adding, on spot, HCl solution, in order to decrease and maintain acid pH (<2) in the samples. This had as a result to decrease the cesium molecular mobility and consequently, the ^{137}Cs loss through deposition in the sample's tank sides. Hence, the samples were chemically treated and measured in the laboratory in order to determine the ^{137}Cs activity concentration. Sufficient amount of HCl was further added in the seawater that was mechanically moiled, resulting with a pH up to 1-1.5 for all the samples. During the moiling step, 1 ml of ^{134}Cs solution was used as a radiotracer, with nominal activity of 2 Bq, in order to determine the chemical efficiency of the method. Ammonium Phosphomolybdate Hydrate (AMP) was also used as adsorbent, in order to concentrate ^{137,134}Cs in particulate bulk form. 15 gr of AMP were magnetically moiled for about 10 minutes in water acid mixture (pH=1.5) and then dissolved in the seawater sample. After 3-4 hours of seawater stirring, the solution was left to settle (for 6 hours) and with continuous spillages the final bulk samples were placed in cylindrical plastic containers of 6.9 cm diameter and 2cm height for further measurements retrieved. The ^{137}Cs activity concentration was measured using a high purity Ge detector of 50% relative efficiency. The samples were placed in touch geometry with the detector's window, inside Pb shielding and measured for an acquisition time of 24 h. The ^{137}Cs activity of the samples was derived in Bq/m^3 from the gamma ray spectra using the SPECTRW spectrometry software package and the formula below [6].

$$Ativity = \frac{Counts}{e_{ff} * rec * t * V * I_{\gamma}}$$

Where t, is the time measurement of each sample (24 h), e_{ff} the absolute efficiency of the detector, rec the chemical efficiency of the methodology (~ 95%), V the volume of each seawater sample (20L), and I_{γ} the gamma ray intensity for the 661.66 keV.

The energy and efficiency calibration of the Ge detector were performed with a ^{152}Eu source of known activity (1.21 μCi) prepared at NCSR "Demokritos" in the same cylindrical plastic containers with the samples and placed under the same geometry conditions on the detector's window as the samples.

3. Results and discussion

The results of all stations are depicted in figures 2 and 3. All figures represent vertical distribution of ^{137}Cs activity concentration in combination with salinity and temperature. The measurements indicate that the maximum ^{137}Cs levels were observed in South Aegean Sea, especially in the regions where waters invade from Dardanelles Straits. This validates that the water circulation transfers water masses through Dardanelles Straits towards the ecosystem of North (A1) and Northeast (NA1) of Lemnos Island. The water circulation creates a high ^{137}Cs concentration (6 – 8.5 Bq m^{-3}) at surface water (0-80 m), in comparison with the other regions of Aegean Sea. Furthermore, the levels of ^{137}Cs activity at the exit of Dardanelles Straits or southeast of Lemnos Island (A2) were lower than those in the region north of Lemnos, since the waters from Dardanelles Straits are not transferred towards north of Lemnos Island. These results are consistent with the measured salinity and temperature for this region and indicate that waters from A2 region do not originate mainly from Black Sea. This is evident since the water exhibit high salinity and temperature values indicating that the nature of the waters comes mainly from the Aegean Sea. On the contrary, in the stations at north (A1) and northeast of Lemnos Island (NA1), the nature of the water is originated from the Black Sea water masses. As far as the southwest of Samothrace Island is concerned, ^{137}Cs activity concentrations were 20% lower (with mean concentration of ^{137}Cs at 6.5 Bq/m^3) than those of the regions A1 and NA1, while salinity and temperature were almost stable.

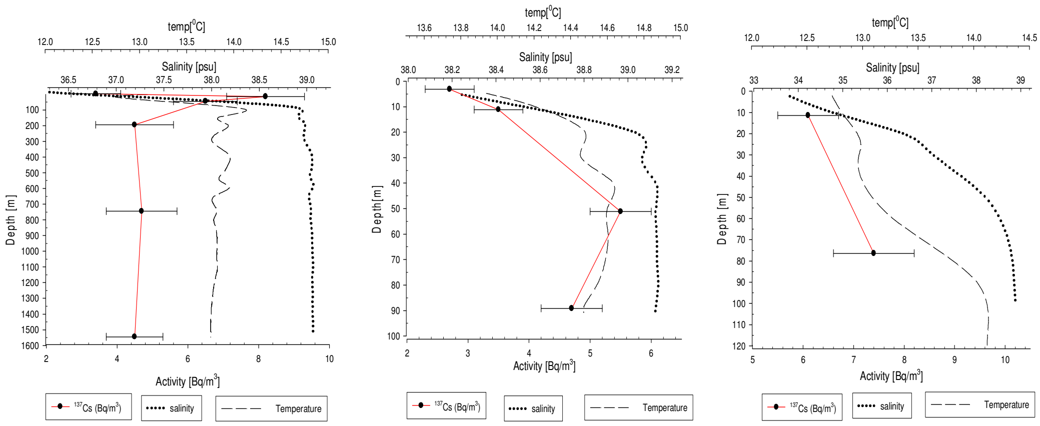

Fig. 2. Vertical profile of salinity, temperature and ^{137}Cs activity in (a) A1 deep basin, (b) A2 region and (c) NA1 region.

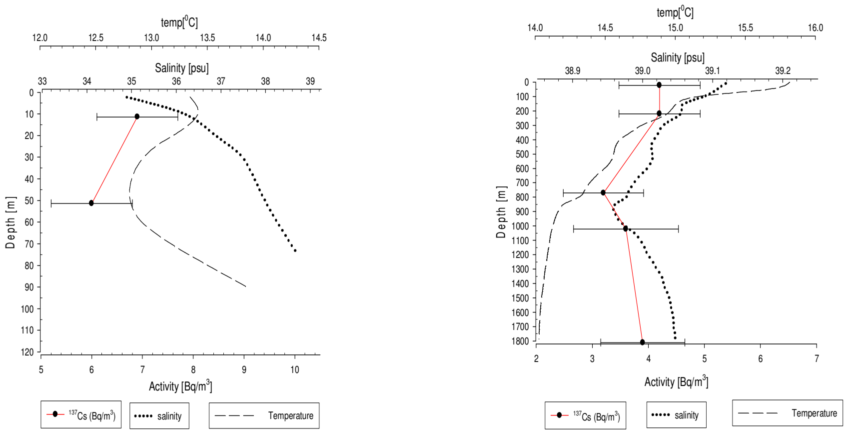

Fig. 3. Vertical profile of salinity, temperature and ^{137}Cs activity in (a) NA8 region and (b) A10 deep basin.

On the other hand, ^{137}Cs concentrations in South Aegean Sea (A10) were lower than those of North Aegean and ranged between 3 to 5 Bq/m^{-3}. Cretan Sea (A10) presents the major interest since the maximum activity ^{137}Cs concentration was observed on surface waters and the minimum at 800 m. This phenomenon may be interpreted from invasion of the transient Mediterranean water.

4. Conclusions

The trend of ^{137}Cs exhibits a decrease from the surface to the intermediate layer, and then an increase towards the bottom of the basin. The deep water masses are characterized by the maximum ^{137}Cs activity concentrations, while the Levantine water has the lowest values compared with the values of the vertical profile.

These data were obtained two years before the accident in Fokushima, so they can be considered as a data base for this period. These data can also be compared with future measurements, and can give us valuable information of potential influence of Fokushima accident to the Hellenic Seas.

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